

Design and Simulation of Optical Power Splitter By using SOI Material

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ABSTRACT

The present paper reports that the simple technology-compatible design of 1×2 optical power splitter is proposed. The device is based on symmetric Y-branch comprising of S-bend waveguide. Initially, a symmetric Y-junction based 1×2 optical power splitter is designed, which can deliver the best result in simulated performance. Three dimensional Beam propagation Method is applied for this work, where S-bend waveguides are designed for optimal field matching in each Y-branch section of the optical splitter. Chosen wavelength in guiding media is $1550\mu\text{m}$. Finally studied about insertion loss, attenuation, and splitting ratio. The SOI rib-waveguide dimensions (height, width) leading simultaneously to single mode propagation.

Keywords: Beam propagation method; Insertion loss; Optical splitter; Y-junction Wave guide; Rib waveguides Silicon-on-Insulator.

INTRODUCTION

Optical Power splitter is one of the key passive components in subscribes networks of optical communications to split the power of the optical signal into two branches. Various research groups have designed, fabricated and demonstrated several techniques like Y-branch splitter,

multimode interference based splitter and so on, for achieving a compact, low-loss and cost-effective optical splitter. Among these, Y-branch optical splitter is much popular because of its design simplicity, where the basic unit of this $1 \times N$ optical splitter is the Y-branch 1×2 optical power splitter. Further, silicon-on-insulator material based splitters provide some additional advantages like low

propagation loss, high reliability and good fiber coupling efficiency due to its excellent inherent mechanical and thermal material properties.

In this paper, initially, a symmetric Y-junction-based 1×2 optical power splitter in silicon-on-insulator material is designed. The design is optimized for delivering the best possible simulated performance in terms of total insertion loss among the outputs. Finally, the simulation results of the proposed technology-compatible design of 1×2 optical splitter have been compared with that of the best designed splitter in terms of the same parameters showing the compromise in the design.

Design of a symmetric Y-junction optical splitter

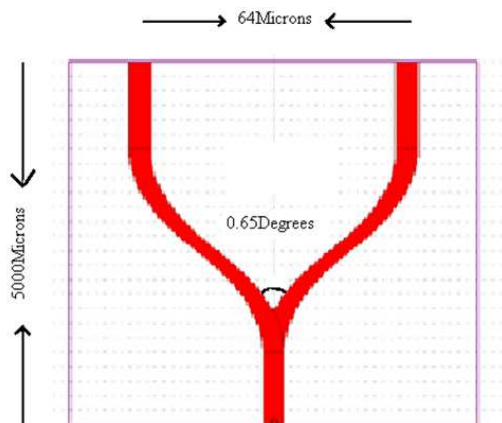


Fig.1 a schematic diagram of 1x2 Optical Power Splitter

The basic unit of the 1×2 Y-branch section optical splitter comprises of an initial straight waveguide, an S-bend waveguide. A pair of S-bend branching waveguides is considered in this case because of its

continuity in light propagation path with the S-bend waveguide, which results in a slight improvement in overall performance of the splitter. By symmetrically optical power splitter has been designed after considering silicon-on-insulator material parameters.

The BPM software tool has been used for the simulation work. The simulator is based on the unconditionally stable finite difference method algorithm of Crank and Nicolson. This method works with discrete values of the field, in the transverse direction (based on a numerical mesh) and the refractive index, along the direction of propagation (by steps of propagation). In this simulation, the number of points in mesh of 5000 and the propagation step of 1.55microns have been considered for the device dimension of 5000 μm (length) 64 μm (width).

For a typical simulation, a monochromatic light is considered as input that causes the propagation of coherent field, which is governed by Helmholtz equation. In actual simulation, the paraxial or the wide-angle approximations to this equation is used, whereas the scalar or semi-vectorial paraxial Fresnel approximation can be used for small-angles of light propagation. In the simulation, refractive indices of the core and the cladding have been considered as 3.475 and 1.444 and silicon refractive index is 3.475 respectively at the wavelength of 1550 nm. The width and height of the straight waveguide and the branching waveguides are considered as 5 μm each in order to achieve a single mode light propagation¹. The layout design has been described in Fig. 1, where the inset of the figure shows one of the Y-branch.

SIMULATION RESULTS AND DISCUSSION

The simulation has been done using BPM tool by considering the propagation of an optical signal of fundamental TE mode through the 1×2 optical splitter, where Figs 2, 3, 4 and 5 show the corresponding simulated results at 1550 nm, in terms of the variation of optical/electrical field and effective refractive index along the device length and across the device-width respectively. The simulated value of the average insertion loss of the splitter has been found to be 0.0813dB for TE-mode at this wavelength.

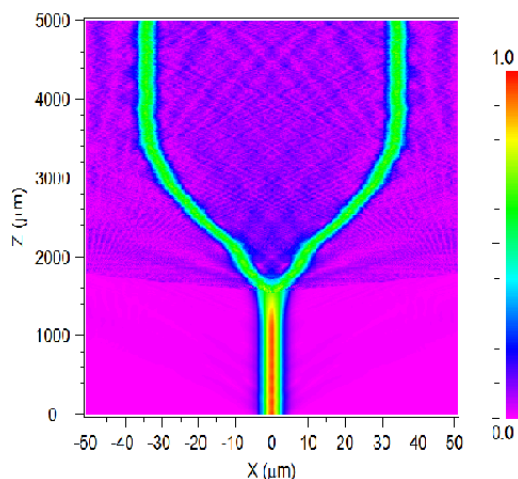


Fig.2 Simulation of the optical field along the Length

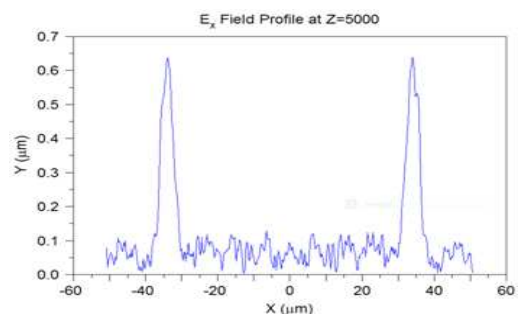


Fig.3 Simulation of field profile along its length

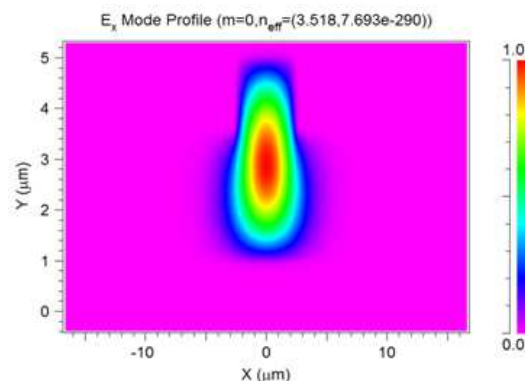


Fig.4 simulation of mode profile and refractive Index

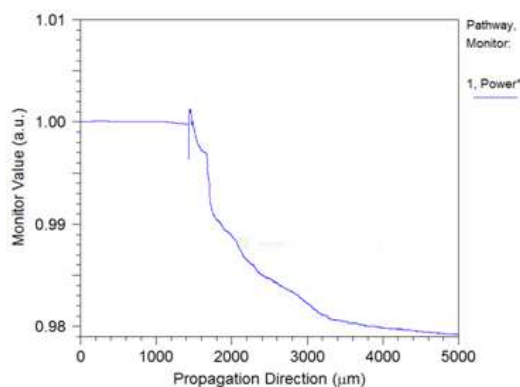


Fig.5 simulation of propagation along its length

Table I
Variation of Component width with Attenuation

Component Width (μm)	Transmitted Power(Watts)	IL (dB)	Attenuation (dB/m)
3	0.979	0.092	18.4
4	0.980	0.087	17.5
5	0.985	0.065	13.1

Attenuation Coefficient of the power splitter has been found to be 16.33dB/m for TE- mode at this wave length. Table. I, II show the variation of component width, Branching angle with transmitted power, Insertion loss, and attenuation coefficient.

Table II
Variation of Branching angle with Attenuation

Branching angle(2θ) (Degrees)	Transmitted power (Watts)	Power loss (dB)	Attenuation coefficient (dB)/m
0.55	0.982	0.078	15.77
0.56	0.982	0.078	15.77
0.57	0.982	0.078	15.77
0.58	0.984	0.070	14
0.59	0.984	0.070	14
0.60	0.980	0.087	17.5
0.61	0.982	0.078	15.77
0.62	0.982	0.078	15.77
0.63	0.982	0.078	15.77
0.64	0.984	0.070	14
0.65	0.985	0.065	13.1
0.66	0.984	0.070	14
0.67	0.984	0.070	14
0.68	0.984	0.070	14
0.69	0.984	0.070	14
0.70	0.984	0.070	14

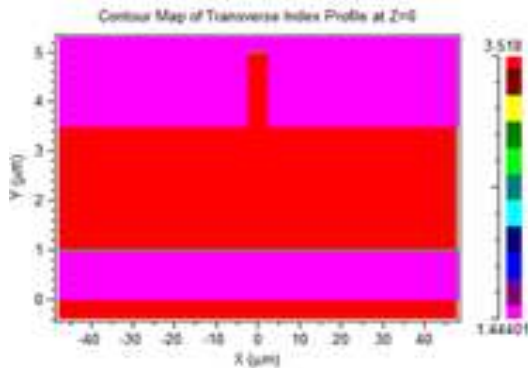


Fig.6 Simulation of the index profile

$$\frac{W}{H} \leq 0.3 + \frac{r}{\sqrt{1-r^2}}, \quad r = \frac{h}{H} \geq 0.5 \quad (1)$$

Where in equation.1, $r=h/H$ is the ratio of slab height to overall rib height, and W/H is the ratio of waveguide width to overall rib height (Fig. 6). Their analysis of the

waveguides was limited to shallow etched ribs ($r > 0.5$) and the waveguide dimensions were assumed to be larger than the operating wavelength. The analysis was based on the assumption that higher order vertical modes (i.e., modes other than the fundamental mode) confined under the rib, were coupled to the outer slab region during propagation, therefore yielding high propagation losses for the higher order modes. For a better understanding, we will also consider the etching depth (P) $P=H(1-r)$ which directly gives the edge height of the rib waveguide¹⁻⁶.

$$\beta = 2\pi n_{\text{eff}}/\lambda \quad (2)$$

Where in equation.2, β is the propagation wave number with n_{eff} the effective index and λ the operating wavelength fixed at $1.55\mu\text{m}$.

$$\alpha = 10\log_{10}(P_1/P_2) \quad (3)$$

Where in equation.3, α is the Insertion loss of an optical splitter is usually measured in decibels. If an input power P_1 (1 watts) results in an output power P_2 .

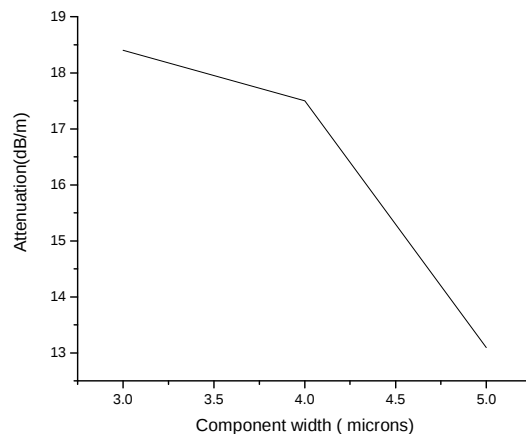


Fig.7 Plot between Component width with attenuation

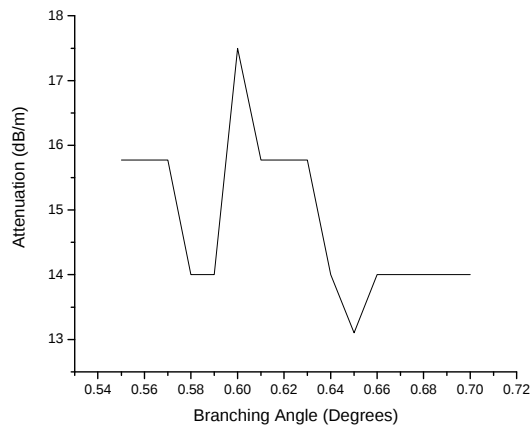


Fig.8. Plot between Branching Angle with attenuation

waveguide is almost symmetrical means 50/50. Width of waveguide is depend on splitter characteristics if the width is varied between 3-5 μ m and by fixing components (height, wavelength, refractive index difference) it is observed that the transmitted power increases, and also observed with the increase in width of the waveguide the transmitted power also increases. As well as it should vary with branching angle. It was found in fig 7, 8 and Table. II. The attenuation and Insertion loss depends on the width of the waveguide, Branching angle.

CONCLUSION

The overall simulated performance of the proposed technology-compatible design of 1 $\times$ 2 optical splitter has been found to be comparable in terms of insertion loss ($\sim$ 0.01 dB higher) when compared to the results obtained from the best design; however, it should bring down the difference between the theoretical and experimental results with a better post-fabrication device performance. The splitting ratio of this

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